LEARNING PROCESS

&

MEASUREMENT OF SCIENCE ABILITIES BY USING COMPREHENSION TESTS IN PHYSICS

— A PILOT STUDY

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All the errors are, of course, mine.

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Introduction

Learning occurs in the individual when he observes, reads, thinks, reacts mentally or tries to solve new problems on the basis of his previous experiences. Learning process involves understanding new ideas and concepts. It is a process of change in individual behaviour under a set of stimulii. Learning of new things consists of all sorts of changes which the mind undergoes by the given set of conditions. Thus learning can be considered as the total outcome of these changes and the total changes are the product of the whole learning experiences provided. The resultant of interactions between the individual and environmental stimulii can be considered as measurement of learning.

There are several factors like motivation, drives, reinforcement, background knowledge, replication etc., which influence the learning process. It is very interesting to observe the pattern of this change in learning under a given set of experimental conditions. The present study aims at highlighting this mode of learning and its implication in the students' present and future performances. For this purpose, comprehension passages have been taken. Actually comprehension is the main function in the learning process and this learning process is depicted by answering questions prepared on the basis of the ideas given in the passage. The responses of the students are reflected through the answers they make after reading the passage. The successive scores which the students give in different trials, give the rhythmic pattern of learning which is peculiar to the individual.

Physics has been chosen as the subject of comprehension tasks. The reason for this is the relative importance of learning science in present days. The modern world is a world of science. In order to improve the science education of our country, we are to know in what way the scientific ideas get into the heads of our pupils. Again the subject physics is related to complex scientific ideas and mathematical concepts, the understanding of which requires persistent, learning, scientific aptitude and other mental abilities.

Passages have been so selected that its comprehension necessitates a background in the subject, and the capacity of the individual to learn scientific ideas. The tasks are made for Class XI science students. It is very important to know how young students understand scientific ideas and learn them in course of their repeated reading. The knowledge of learning pattern of the learners will enable the teachers and educators to modify their methods of teaching according to the learning trends of the students. This study is aimed at a modest attempt to investigate the learning process and to categorise the individuals according to their pattern of learning and to find out what relationship these learning parameters have with the science aptitude scores, the physics achievement score and total achievement scores.

The present author has tried to find a sensitive index for measuring certain mental abilities in the context of science. These mental abilities involve quick comprehension, high retentivity, persistence in thinking, understanding relationship in the scientific ideas, and ability to apply the ideas in new situations. The items of comprehension task have been prepared with these points in view. Moreover, the responses of the students

indifferent trials give the indications of the above abilities. The measurement of these traits from the observed scores of the students in different trials might give an index score which might precisely identify the scientific abilities in an individual. Identification of science abilities is a very important task before the country, for this enables the educator to give proper guidance in educating them. The indices derived from the measurements of scientificabilities may naturally help immensely in identifying science talent.

In this study, attempts have been made to

1. classify broadly the different learning process of the individuals according to their abilities;

2. find out unique learning parameters of the individuals and their relationship with achievement and aptitude;

3. explore the possibilities of a better index for measurement of scientific abilities from the scores of successive trials.

On the whole, the present study intends to know how far the learning pattern of the learners identifies their abilities, aptitudes and potentialities in science learning.

Preparation of comprehension tests

The tools which were used for measuring the learning process were some comprehension tests in physics. Two passages containing scientific ideas were finally used.

At first five passages were selected. The subject matter of the passages is not included in the usual syllabus of H. S. students. But basic definitions and scientific terms used in the passage are however, not unknown to them. The test is prepared for XI Class H. S. students and they are very likely to understand the terminologies. The students were expected to comprehend new scientific concepts with the help of their previous knowledge in science.

The matter of the passages was taken from several books on science. Each passage was enriched with scientific ideas relevent to the central theme. The contents of the passages were collected from different books so that at least 20 items might be selected from ~~these~~ each passage.

Much care was taken to make the language simple. Though the test was meant for students of English medium schools still difficulty and complexity of language were considerably removed. Proper edition and modifications were made during the preparation of the passages to make the language of the passages to make the language of the ~~passages~~ simple and comprehensible. The scientific ideas were present in a manner so that they would require mental abilities and aptitude to comprehend the implications. Difficult words, phrases and ambiguous expression were, however, carefully avoided.

About twentyfive items were initially constructed from each passage. Completion type of tests was preferred in the present case. Multiple choice type test, widely used in comprehension items, were avoided because limited

scores of the individuals (where full score was 20 at the final stage) would be much affected by guessing. Secondly, at least twenty items were necessary for the purpose but it is extremely difficult to prepare twenty multiple choice items consisting of 20x5 = 100 distractions from a passage containing limited number of sentences, in which case the distractions are not likely to be closer. Thirdly, in the usual learning process a student learns a particular idea from the universe of all ideas in the passage and tries to distinguish them from others which he identifies from the passage by comprehension. But in multiple choice tests, they are given a limited number of ideas in limited number of distractions and an artificial and restricted learning situation is created. On the contrary, the answers in the completion items depict real learning pattern of the students provided an answer to a particular item is unique, and independent and a true measure of comprehension.

Again, it is also difficult to prepare completion items which will require ability of comprehension to answer them. Here the subject is physics and so it is easier to have the answers unique and independent. A completion test suitably measure the ability of scientific comprehension which has been operationally defined as explaining, analysing and synthesising ideas, finding relationship between the scientific concepts and their application to newer fields.

Keeping this definition of comprehension in view, about 25 items were prepared from each passage. Each test item was reviewed and edited several times. For try out the test was administered on XI class science students. On item analysis extremely difficult and very easy items were rejected. Some items were re-edited and reformed. Out of the five passages two passages were finally selected and the difficulty values of items of these passages were between .35and .65. The items were also found having good discriminating power. The

item difficulty value and discriminating power were calculated from Davis chart. The number of items of each passage were 20 at the final stage.

The two passages were of equal sizes. The sizes of answersheets (attached in appendix) each containing 20 items were almost equal. The two passages are

Passage A - Atomic structure

Passage B - Radar (See Appendix).

The reliability of the test was found by (1) Test retest method and, (2) K. R. 20 formula. Test retest method was given to the students after an interval of one day. The corr. of the two scores were .81 in passage A and .73 in passage B. This gives the stability of the test. Again since the items are almost homogenous K. R. 20 formula was applied. The interval consistency reliability of the passages become -

Passage A = .75

Passage B = .69

The content validity of the items were tested. The passages and the answersheets were sent to two psychologists and two teachers to shed their opinion whether these could measure comprehension or not. They gave some suggestions to modify a few items. After modifications they unanimously accepted them as comprehension items.

Moreover, some students were given the tests and they were asked to express how they arrived at their answers. From the nature of their explanation it was understood that the items required comprehension.

The parallelism of two passages were too tested. The two mean scores of the two passages were calculated. By 't' test they were found not to differ significantly. Again s.d.s of the two tests also did not differ significantly. This showed that the two tests were parallel.

Sample

The sample of the study consists of students of two institutions. One is Narendranath Vidyamondir, Calcutta-36, a higher secondary school in Calcutta. The students of Class XI Science were selected. The students of the school have mostly come from middle class families. The average of percentages of Passing Pqwwint H. S. Examination of last five years is about 95%. The school possesses a good science laboratory.

The second institution of Birla Institute of Technology and Science, Pilani, Rajasthan. Here almost all students have come from upper middle class and rich families from different parts of India. The authority of Institution selected the students by administering various types of admission tests. The students of B. I. T. have just passed H. S. examination and are now students of 1st year B. E. class. The students of this Institution have been taken to compare the learning abilities of these selected group with the ordinary XI class science students of Narendranath Vidyamondir.

The medium of instruction in both the institutions in English. So the verbal factor will not affect much in our study.

The number of students taken from Narendranath Vidyamondir is 26 and that from Birla Institute of Techology is 24.

The students of each institution were classed into two random groups. Thus each group of Narendranath Vidyamondir consists of 13 students. Similarly the students of Birla Institute of Technology were also classed in two random groups each group consisting of 12 students. A larger number of sample would have enhanced the degree of precision and generalisability of results and their interpretation. But to handle such a huge data is not feasible in the limited time and as such the researcher has given up the idea of collecting data from a larger sample.

1st year B. E. Students who have just passed Higher Secondary Examination were taken for tests. The second group consists of XI class science students. The two groups are not comparable. But the students of B.I.T. were taken for tests for the following reason. The learning patterns of highly meritorious science students were also necessary for comparing with those of ordinary science students. First year B. E. students are having a good back ground of the subject matter. Investigation was sought how the mode of learning of meritorious students having sufficient back ground differs from that of ordinary science students.

Procedure for collection of data

Two passages, one on RADAR and the other on ATOMIC STRUCTURE were given to two groups of an institution. In each institution the teachers were present on the class. They were told that these tests have been given to them to know their scientific abilities. All the students took much interest in it and they tried to show their best performance according to their abilities.

The passages (two passages to two groups) were given to them. The sheet was folded so that they may not read it at the time of distribution. The content was written on one side of the passage sheet. The time for reading in one trial the passage was fixed as five minutes. In five minutes, a man can read the passage orely two times at a moderate rate. But the rate of mental reading is different to different students. Students may mentally read once, twice or more than that. Our aim is to measure how much they have comprehended in the given period. Their amount of comprehension will be reflected in the next five minutes while they will be answering the items prepared on the basis of comprehension of scientific ideas given in the passage.

The following instruction was given by the teacher to the students in relation to the technique of answering the items. The students should open the passage sheet just after the announcement of starting. Theyare allowed to read and think the passage for five minutes. They are to fold the sheet and stop reading just at the moment while the teacher will tell them to stop. For the next five minutes the students are allowed to fill up the blanks in the completion type answer sheets already supplied to them. They are not allowed to see the folded passage sheet while answering the items. Just after five minutes, the teacher will call them to stop answering and start reading the same passage for the 2nd time. The 1st set of answer sheets will be collected and the second set of answer sheets will be given in a folded way.

Thus second ~~trial~~ trial starts. After five minutes, the students are to stop reading and start answering of opening answer sheets for the next five minutes. In the same manner five trials will be taken. The instruction for answering the passage has been given in the answer sheet (see answersheet in appendix) which runs thus.

"On the basis of the passage you have read, fill up the following blanks with appropriate word or phrase which will make a complete scientific sense."

Scheme of experiment

Trial	Instructions	Time	Cumulated Interval
I	Passage reading	5 mins.	0 — 5 mts.
	Signal		
	Test	5 mins.	6 — 10 mts.
	Signal for next trial	1 min.	11 mts.

The same sequence was followed upto 5 trials. Almost 1 minute was spent in giving signals for stop reading and stop answering.

The instructions were made clear to the students before starting. When the students understood the procedure clearly, the experiment was started. 5 answer sheets from each students were collected.

The number of answer sheets in different passages from different schools is the following :

Passage	no. of answer sheets	B.I.T. Pilani (B.E. 1st year)	N.N.V. Calcutta (XI)
Rudder		12 X 5 = 60	13 X 5 = 65
AN ~~structure~~		12 X 5 = 60	13 X 5 = 65

The scores of the students in different schools in different passages are given in Table I. The students are individualised in their code number.

Hypothesis to be tested

(a) The learning curves of the individuals differ significantly.

(b) The last trial scores of the individuals who got identical scores in the first trial differ significantly.

(c) The scores of the students in the first trial differ significantly from the scores of the same students in the last trials.

(d) Average rate of learning is correlated with achievement and aptitude scores.

(e) Acceleration of learning (denoting the power of quick comprehension of the individuals) is correlated with achievement and aptitude scores.

(f) Fast learners and slow learners differ significantly in their achievement.

(g) 'Summated score weighted with learning value' of the trials have no correlation with achievement and aptitude.

Pattern of learning as depicted in the scores of comprehension tasks in Physics

The acquisition of knowledge is a result of the learning process of the individuals. So the learning process is undoubtedly a significant area of psychological study. The educationists recognise the importance of discovering the how, why and what of learning pattern of the pupils. Learning process is a projection of the students' motivation, mental alertness, aptitude background knowledge and other abilities which constitute the potentialities of them.

In the present study, the pattern of learning process has been investigated. Comprehension tasks in physics have been given to science students (XI class students & 1st year B. Sc. students) and their scores have been obtained in five consecutive trials of equal time intervals. The scores will obviously depict the learning pattern of the students. The students will react differently according to their abilities in comprehending ideas.

Here, it has been noticed that the students have gradually learnt items with increase of number of trials. Sometimes, students forget the items which they have learnt in the previous trial. Only in a very few number of cases, it has been seen that the total score in a trial is less than the total score in the previous trial. But such cases are only a few. Generally a trend of increase in scores with the increase of trials has been observed.

The students were given the test only for 55 minutes. So perhaps most of the students have not felt any boredom and fatigue. Their scores in last trials also are not decreased in comparison to the scores of the previous trials. So it can be safely said that the phase of retrospective inhibition has not set to the students at the end of the fifth trial.

It is also observed that in the last trials some of the students have reached their plateau position, but others are still learning items. So the

scores in the given five trials reflects a dynamic stage of learning situation of the students who are reading, thinking, reacting and attempting to comprehend ideas.

In order to find out the learning pattern of the individuals we are to study their learning curves showing the scores in different trials. From the nature of the curve, we can have an idea of the learning process of the individual.

In learning curves, trial numbers are plotted in the X-axis and the scores in the Y-axis. The learning curves of the students of N. N. V. was drawn in blue pencil and those of students of B. I. T. in red pencil. The code numbers of the students have been given in the corresponding learning curves at the beginning and the end. Fig. 2 gives the learning pattern of the students while they were trying to learn the ideas in the passage of atomic structure. The peculiarities of the curves denotes the varied processes of learning of individuals. They also depict the mode of psychological changes of their mind.

The variation pattern in the scores is due to the individual's initial knowledge of the passage before reading and their way of learning. But the subject matter taken in the passage is not related to the syllabus of the students. Also it has been actually found out in try out that almost all students could not answer the item when only answer sheets were given to them before reading the passage. So the possibility that the students may know the items earlier is ruled out and it has been assumed in the study that the initial score before reading the passage is zero.

The observed scores in the trials tell us about the way of learning for the individual. In order to study the characteristics of different learning curves, we are to classify them into certain categories. Each category will contain learning curves characterised by some specific properties of their own.

The following steps were taken to facilitate the derived classification:

At first a scatter diagram is plotted with the scores of first trial in the X-axis and scores of the fifth trial in the Y-axis. So fifty set of scores of fifty students were plotted in the graph (See Fig. 2). X and Y co-ordinates of a point denote the individual's scores in the first and fifth trial respectively. The dot in the Blue pencil denotes the scores of students of N. N. V. and the dots in red pencil the scores of B. I. T.

From the scatter diagram following frequency table was obtained.

1st Trial Score X \ Fifth Trial Score Y	0 - 7		8 - 14		15-20	
	N.N.V	B.I.T.	N.N.V.	B.I.T.	N.N.V.	B.I.T.
0 — 7	3	0	8	1	11	3
8 — 14	X	X	1	2	3	11
15 — 20	X	X	X	X	0	7

Let us call scores from 0 to 7 as low scores, 8 to 14 as medium scores and 15 to 20 as high scores. From the table it is clear that 22 students of N.N.V. and 4 students of B. I. T. have got low scores in the first trial, while 7 students of B. I. T. and no students of N. N. V. have got high scores in the first trial. This clearly differentiates that the students of B. I. T. are possessing greater power scientific comprehension.

From the scatter diagram, it is seen that most of the students of N.N.V. have got low scores in the first trial. These students gets a large number of newer items to learn in the subsequent trials. But most of the students of B.I.T. gets medium or high scores in the first trials. So only a few items are left to be learnt in the next trials. It is difficult to know the learning pattern of these students due to scaling effect.

Actually the students of B. I. T. are much advanced having a good background knowledge. Though the idea in the passage is new, they have easily understood the ideas in the passage by their quick comprehensional power and background knowledge.

The diagram shows that three students of B. I. T. gets medium scores at the end of five trials and there are eleven students getting high scores at the end of five trials. This shows that some students of N.N.V. might be having greater abilities to learn than the three above B. I. T. students. These students of B. I. T. might be having low test motivation.

Now, for better understanding of the learning pattern of the individuals, the students have been classified into six categories as evident in the scatter diagram of scores in first and last trials. (Fig. 2)

(a) Students getting low scores in the first trial and low scores in fifth trial.

(b) Students getting low scores in the first trial and medium scores in the fifth trial.

(c) Students getting low scores in the first trial and high scores in the fifth trial.

(d) Students getting medium scores in the first trial and medium scores in the last trial.

(e) Students getting medium scores in the first trial and high scores in the fifth trial.

(f) Students getting high scores in the first trial and high scores in the fifth trial.

The learning curves of each categories have been made separately in Fig. 3. From the nature of the graphs of different categories we can

explain the learning pattern of the class concerned and distinguish among the different classes in the different modes of learning (See Fig. 3).

(a) Students who have got initial low scores and finally also low scores are slowest in learning. The average rate of learning is very low. They cannot think or concentrate upon a problem properly. Their power of comprehending for newer ideas is less than average students. They have low learning ability.

(b) Students having low scores in the first trial and medium scores in the fifth trial fall in this group. The rate of learning in the beginning and at the end is low. These students possesses low power of comprehension. The students are less intelligent and they learn new items by their persistent efforts with their small capacity for comprehension. They have average learning ability.

(c) Again, some students obtained low scores in the beginning, but high scores at the end of fifth trial. These students are initially slow but steady. With the increase of trials, they learn newer items at a steady speed. Their rate of learning items over the trials is more or less uniform. They are dilligent, attentive and mentally alert.

(d) There are a group of students who gets medium scores all over the trials. Their initial medium scores shows that they are intelligent and have good basis for comprehending ideas. But most probably their test motivation is low. They become satisfied with what they know. Sometimes they falsely think that they have learnt all items and do not attempt to know any more. They are lazy intelligent students. This is due to lack of mental ability to think persistantly.

(e) Another group of students gets medium scores at the beginning and high scores at the end of fifth trial. These students are intelligent as well as

industrious. Intelligence, persistence and perseverance have led them to achive higher scores.

(f) Lastly, there are some students who gets high scores at the very beginning. After a number of trials they get still higher scores. These students are mentally alert, highly intelligent and have patience to learn still newer things. They have a high power of comprehension, strong desire to learn the ideas and a keen apptitude towards the topic. Such students may called having scientific talent in them. In the learning curves of this group it is seen that many students of B. I. T. havereached the final positions in 3rd or 4th trial. This shows that the students of B. I. T. ~~are~~ are not getting much learning materials from the comprehension passage which was actually meant for XI class H. S. students.

These are the broad classes of students who learn ideas in different ways. The mode of learning depends on several factors namely ability of comprehension, apptitude for ideas in physics, motivation, socio-economic background and a number of other environmental factors. The learning curves in Fig. 2 give a picture of varities of learning processes of individuals while comprehending a passage on 'Atomic Structure'.

Measurements of learning parameters

In the previous chapter, we have classified the students into six groups according to their variations of learning abilities. It is interesting to study the different groups in relation to their achievement and aptitude. But the sample size taken here is small and the frequency of different categories of students is less. It is difficult to generalise results on the basis of these small groups.

Moreover, this classification does not give any quantitative measure of their initial learning, rate of learning and acceleration of learning. So a better measure of these learning parameters has been sought from the observed scores in the different trials. The measurements of above parameters will enable us to arrive at an assumed initial score and to know the average rate of learning of the individuals and the trend of his learning in different trials.

In the present study the following model (*) has been taken to find the learning parameters -

$$\hat{p}_{it} = p_{io} + p_{i1} + p_{i2} \qquad \ldots\ldots \quad (1)$$

$$\text{and } e_{it} = p_{it} - \hat{p}_{it} \qquad \ldots\ldots \quad (2)$$

where p_{it} = observed score of individual i on trial t,

$\hat{p}_{it}$ = theoretical score of individual i on trial t,

$p_{io} = e_{io}$ = initial ability for individual i,

$p_{i1} = e_{i1} \times t \qquad (t = 1, 2, \ldots\ldots k)$

$p_{i2} = e_{i2} \left[(t - \frac{1}{2}k)^2 - \frac{1}{12}k^2 \right]$

e_{it} = error of the individual i in t th trial score.

Ref. Roger B. Allison : Learning parameters and human abilities - A technical report.

Theoretical score of an individual can be written as,

$$\hat{p}_{it} = c_{io} + c_{i2}\, t + c_{i2}\left[(t - \tfrac{1}{2}k)^2 - \tfrac{1}{2}k^2\right] \quad \ldots \quad (3)$$

By taking the first two derivatives of equation (3), we get

$$\frac{dp_{it}}{dt} = c_{i1} + 2\, c_{i2}\,(t - \tfrac{1}{2}k) \quad \ldots \quad \ldots \quad (4)$$

and $$\frac{d^2 p_{it}}{dt^2} = 2\, c_{i2} \quad \ldots \quad \ldots \quad (5)$$

from,(4), we see that at midtrial ($t = \frac{1}{2}k$), $c_{i1} = \frac{dp_{it}}{dt}$. So c_{i1} represents the rate of performance i.e., learning at mid-trial. It can also be shown that c_{i1} is the average rate of learning over k trials.

Again from (5) we know that c_{i2} is proportional to the second derivative of equation (3). It indicates whether the individual i was performing relatively better during first half of the learning task than in the 2nd half. From equation (3), it is evident that if c_{i2} is negative the subject was learning more quickly during the first half of the learning task and is positive, if the subject was learning more quickly during the latter half. c_{io}, c_{i1} and c_{i2} are known as learning parameters of ith individuals.

The following assumptions have been taken in regard to the learning parameters

c_{io}, c_{i1}, and c_{i2}.

(1) Learning is a process which can be observed from the performance measures obtained at several equally spaced time intervals or trials.

(2) The performance of an individual on a specified trial t can be expressed as a function of the trial number of t and certain parameters unique to that individual.

(3) The performance score of an individual i in trial t is the total sum of his

(i) initial ability,

(ii) product of rate learning and t

and (iii) the score due to acceleration upto that trial.

Now we are to find out e_{i0}, e_{i1}, and e_{i2} (i = 1, 2, ... 4) from the observed scores of the individuals. This can be obtained from the following matrix equation,

$$e = pw \qquad \ldots \quad (6)$$ (See appendix)

where $e = (e_{i0}, e_{i1}, e_{i2})$

$p = (p_1, p_2, p_3 \ldots\ldots p_k)$

wherever $p_1, p_2 \ldots\ldots p_k$ and observed scores in k trials.

$w = x(xx^1)^{-1}$ where

$$x = \begin{pmatrix} 1 & 1 & \ldots\ldots 1 & \ldots\ldots 1 \\ 1 & 2 & \ldots\ldots t & \ldots\ldots k \\ t-k & 4-2k & \ldots t^2 - tk & \ldots 0 \end{pmatrix}$$

(For deduction see appendix).

In equation (6) p is observed scored matrix and x is weight-matrix for a given number of trials. Both these matrices being known, the parameters e_0, e_1 and e_2 of the individuals can be obtained by the sum of crossproducts of the observed scores on trial t and the appropriate weight for that trial.

In our present study, the subject of comprehension tasks in physics is not included in the syllabus and in the try out it has been found that students could not answer the items when the answer sheet was given before the reading of the

passage. Since the learning task in this study is new to the students, it has been assumed that co-parameters of the learners are zero. So our problem reduces to find out c_1 and c_2 parameters of the learners. From the matrix $c = pw$, the learning parameters c_1 and c_2 were calculated. Table2&3 gives the parameters of the corresponding students of both the institutions.

To find out the learning parameters, only the students of N.N.V. were taken, because in the scores of the students of B.I.T. it was found that most of the students get good scores in the first trial. So in their case the assumption of $c_0 = 0$ is not applicable.

The consistency of the parameters is found in the following way. Average rate of learning (c_1) and acceleration of learning (c_2) of the individuals are calculated from the scores of five trials in the two passages. So two sets of learning parameters were found in the two passages. Only 13 students of N.N.V. were taken. The correlation of two sets of c_1 of the same individuals were .81. Again, the correlation of two sets of c_2 were found to be .76. This shows the consistency of the parameters.

Measurement of scientific abilities by an index-score weighted with "learning value" of different trials.

It has been found in the analysis of graphs in Chapter VI that students getting same scores in the 1st trial differ in their scores in the 5th trial. This is due to difference in their learning abilities. Though the initial background knowledge and learning ability is the same at the beginning, students differ in their learning processes and acquire knowledge according to the unique trait of learning of their own. The learning parameters c_1 and c_2 have been found out and their high correlation with achivement and aptitude shows that the capacity to learn things is an important factor in their way of achieving knowledge.

From the analysis of the graphs of in Chapter VI and the relationship of learning parameters with the achievement and aptitude of the students, it can be inferred that we donot get much information from the score of the 1st trial score. It gives his learning at the first stage and initial potentiality. It does not give much information about how he understands, reacts and attempts to s the problems after reading. Mental changes and the interactions of the learning task are not depicted in the first test score. But the global nature of mental processes will throw more light on the students achievement, aptitude and future possibility of acquiring knowledge in the field.

A better index-score is thus investigated which can reflect the initial potentiality as well as his capacity to learn ideas in different trials. The summated score of the individual being weighted with its difficulty value and 'learning value" at the corresponding trial will perhaps measure the students' initial knowledge scientific aptitude, rate of learning and retentivity. In other words the new index can measure the amount of scientific ~~talent~~ abilities in a sensitive way.

In the present study, the difficulty value of the items lies between .35 to .65 (Chap.2). For conveniences they have been assumed to be homogeneous. Now individuals will answer the items in different trials in their own way. The score in the last trial also does not give the process in which he has learnt. Because some students might have learnt them earlier while the others latter. So the 'learning value' of answering items in different trials is different. The student who learns the item in the second trial, has answered it by reading and thinking it twice, once in the first trial and again in the second trial. So the student who learns the item in the second trial has less learning capacity than the student learning it in the 1st trial. In this way the learning value (hence the performance score) of a correct response becomes gradually less as the student answers it in subsequent trials. It is generally accepted % that quick understanding is a criterion of measurement of abilities. So it has been hypothetically assumed that the 'learning value' i.e., the performance score of the correct response of an item in ith trial is equal to $\frac{t-i+1}{t}$. So that the performance score for the newly learnt item in the five trials will be 1, .8, .6, .4 and .2 respectively. Since the number of newly learnt item in the ith trial = $a_i - a_{i-1}$ the score on the ith trial of the individual = $(a_i - a_{i-1}) \times \frac{t-i+1}{t}$. The total score of an individual in this new index will be the summated score are five trials. An individual's score in the new index will be s_w

$$s_w \quad \sum_{i=1}^{5} \frac{(a_i - a_{i-1})\,(t-i+1)}{t}$$

s_w = Index-score weighted with learning value of the item.

where a_i = items correctly answered in ith trial

a_{i-1} = items correctly answered in i-1th trial.

t = total number of trials = 5

The following assumptions have been made in this index.

(a) The index is the summated score of all the trials.

(b) The score of an item learnt is dependent on the number of trials.

Score in ith trial = $\frac{t-i+1}{t}$

(c) The number of newly learnt items in the ith trial is $a_i - a_{i-1}$. Now fluctuations of items may occur in different trials. A student answering an item in the 1st trial may make mistake in the second trial. In that case $a_i - a_{i-1}$ will be negative provided he has not learnt more items. Then the score weighted with its learning value will be subtracted because he has not learnt the item properly. Thus it can be proved that fluctuations of items does not affect the formula.

From the observed scores at different trials, the summated score a_w was calculated for each individual which has been shown in table 4. We are to see whether it gives more information about the students' mental abilities.

Besides first trial score, the new index of scoring aims at measuring other learning parameters too. More emphasis in learning items in different trials has been given. Moreover the ability of quick comprehension is also measured by giving more weightage i.e. 'learning value' in the preceeding trials. The retentivity and the consistency of the students is also measured, because forgetting of items is discouraged by giving negative scores in those items. So the new index is perhaps measuring some additional abilities in learning science topics.

Achievement and aptitude of the students

In order to find out the relationship between learning parameters, and achievement and aptitude, we are to find out the achievement and aptitude scores of the individuals.

For achievement, the scores of the last annual examination of Narendranath Vidyamandir were taken. The scores in physics and the aggregate were taken. School scores are likely to be unreliable. The correlations of the scores of the students of last three year with the Final Examination scores were found out. The correlations are .81, .73 and .84 respectively. This gives, to some extent, the reliability of their achievement scores. Since standard achievement test of XI Science students was not available, the above scores were taken as achievement scores of the students.

Again, an aptitude test in Physics was given to the students. This test has been taken from science. Aptitude test of 1964 in Physics, administered by department of Science Education, NCERT for Science Talent Search. It has been supposed that the given test has high reliability and validity.

In Physics aptitude test 20 factual type items & and 15 thought type questions in physics were given to the students. The items were multiple choice having 4 distractions in each item. Corrected score of the individuals were found out by the formula -

$$C = R - \frac{W}{3}$$

where C = corrected score

R = number of correct responses

W = number of wrong responses.

Analysis of data

It was not possible to compare the six groups in Chapter V in relation to their achievement and aptitude because the frequency in each group was small. Rank difference method was taken for finding correlation, because the sample is small. For one passage only 13 students were available.

The correlation between first trial score, and achievement score, physics achievement score and aptitude score is .74, .79 and .85. The correlations of average rate of learning (c_1) with achievement of physics and aptitude scores are .71, .69 and .79.

The correlation between c_2, and achievement physics scores and aptitude is .852, .734 and .884.

The correlation between c_w and achievement, physics and aptitude scores is .827, 842 and .949.

Findings

The whole study intends to find out important abilities of students relevent to their learning process.

By analysing the learning curves of the individuals following inferences can be drawn.

The students of B.I.T. get initially higher scores than those of N.N.V. This is perhaps due to better background knowledge and power of quick comprehension of those students.

The learning parameters of students of initially high scoring groups are not comparable, since they are unable to learn newer items due to scaling effect.

From the classifications of learning curves of students, it is obvious that students having same scores in the first trial differ in their scores in the fifth trial. So it can be said that the first trial scores in comprehension tests are not sensative enough to predict the abilities of the students.

In the third chapter we have six classes of learners. Let (a), (b), (c), (d), (e) and (f) represent the students in the corresponding group. It is evident from the graphs of (a), (b) and (c) that in learning and comprehending items (c) > (b) > (a).

Again (f) is superior to (e) in learning abilities. It is difficult to compare the static group (d) whose first and fifth trial scores are medium with other groups. The comparison of the groups in relation to their achievement and aptitude was not possible, since the number (d) students in the groups was small.

In the next chapters, c_1 (average rate of learning), c_2 (acceleration of learning) and c_w (an index score for measurment of science abilities) have been found out. They are derived from the scores of different trials, we are to see which of the measures would give more meaningful results. Again since

rank difference method has been applied for finding correlation the high correlation is expected.

Since the sample size is too small so the method of taking partial and multiple correlation was not taken to draw conclusions about the independance of the parameters over c_1.

The sample size being very small the conclusions and inferences drawn are tentative and provisional.

We have seen -

(1) The correlation of 1st trial score with achievement, physics and aptitude scores are .743, .794 and .855.

(2) Again the correlation of c_1 i.e., average rate of learning with achievement, physics and aptitude scores is .684, .695, .850.

(3) Also c_2 i.e., 'earlier versus late' learning has correlation .852, .734 and .784 with achievement, physics and aptitude scores respectively.

The students' scientific abilities which mostly depends on his achievement scores and aptitude scores are highly correlated with the students first trial score, c_1 i.e., the average rate of learning and c_2, the capacity of early learning.

An index, for identification of science abilities has been investigated in Chapter 4. In this index score c_w care has been taken so that it will give more information about the individuals. The index measures the rate of learning and rate of early comprehension to some extent. Patience, retention and persistence in thinking is also taken into account in this index.

The index c_w has high correlation with achievement, physics and aptitude scores of the students.

Corr. of

	correlation of 1st trial score	index score "σ_w"
Achievement	.743	.827
Physics	.794	.842
Aptitude	.855	.949

The above correlation table show that the index σ_w has greater correlation with achievement, physics score and aptitude than the 1st trial score. We can, therefore, infer that first trial score does not give us adequate information about students' mode of learning, his process of ge acquiring knowledge, his persistent thinking pattern on a comprehension passage. But the new index measures the above learning abilities to a greater extent. So it can be said that the index score σ_w measures probably scientific abilities to a greater sensitiveness than the 1st trial score.

Limitations and suggestions for further studies

Limitations

(a) The researcher has felt difficulty at every step to generalise his results due to small sample size in each categories of chap. VI. The sample size was made in order to analyse learning curves of the individuals and compute their learning parameters and index-score. It is not feasible to compute them within a short period.

(b) The items of the completion type tests have been assumed to be homogenous though their difficulty value ranges from .3 to .75. This has been assumed for convenience of scoring. The 'new index score' would have been more sensitive, if the difficulty value of the items were taken into consideration.

(c) Rank difference method has been taken to compute correlations, since the sample size is 13 only in each group. In this methods, spurious correlations are likely to occur. Generalisations are made on the basis of rank difference correlations. So the results obtained and their interpretations due to subject to further verification on larger samples, with more sensitive tools and by adopting more precise statistical techniques.

(d) The number of items in a passage is 20. From this, it is difficult to find out the learning parameters of the individuals. By giving different passages to the individuals, more consistant learning parameters can be obtained from the mean of them in different passages.

(e) The formula of c_w can still be modified by giving weightage to the difficulty value of the items.

(f) The weightage of the [learning value] of the trial can also be modified.

(g) Initial assumed score of the individuals has been taken to be zero, for the content of the passage was not included in the syllabus and students

did not answer the items before reading. But students of the experiment might be knowing the items earlier before reading. So calculation of e_1 and e_2 ah has been approximated by taken $e_0 = 0$.

(h) The number of items and the number of trials were less. More trials and good number of items would have increased the ~~sensibility~~. Eliminate

(i) The school scores are highly reliable so the predictions are also ~~high~~. unreliable.

Further Studies

The learning process of individuals throw much light on the individuals mental potentialities. The following further investigations can be carried out to get newer important results.

(a) The different groups in Chapter VI can be compared with respect to their achievement, scientific aptitude, power of retention and other external criterias.

(b) The relationship between learning parameters and other external criteria can be further investigated by more sophisticated techniques.

(c) The reliability and validity of the index is not at all determined. By taking larger samples, using more precise tools, applying accurate statistical techniques and taking all sorts of ideal experimental conditions. The high reliability and validity of the formula will give easy, useful and sensitive index for measurement of ~~talent~~. science abilities

(d) Only two comprehension passages on Phyuics have been taken. Passages from Mathematics, chemistry and other science subjects may also be taken. The learning parameters and index score e_w can be derived and it can identify scientific ~~talent~~ abilities in a more precise way.

(e) The number of wrong responses and fluctuations of items can be measured & their relationship with the learning parameters and external criteria can be found out.

(f) The answer sheet can be given after one or two day and the students may be allowed to answer the items without reading the passage. The retention thus obtained can be ex compared with learning parameters.

(g) The learning parameters will find out important traits of the students so that important predictions about his learning abilities can be made.

(h) The sensitiveness of σ_w can further be proved by taking larger sample.

(i) The sensitiveness of σ_w can also be increased by taking difficulty value of the items into consideration.

A P P E N D I X

TABLES, PASSAGES & ANSWER SHEETS

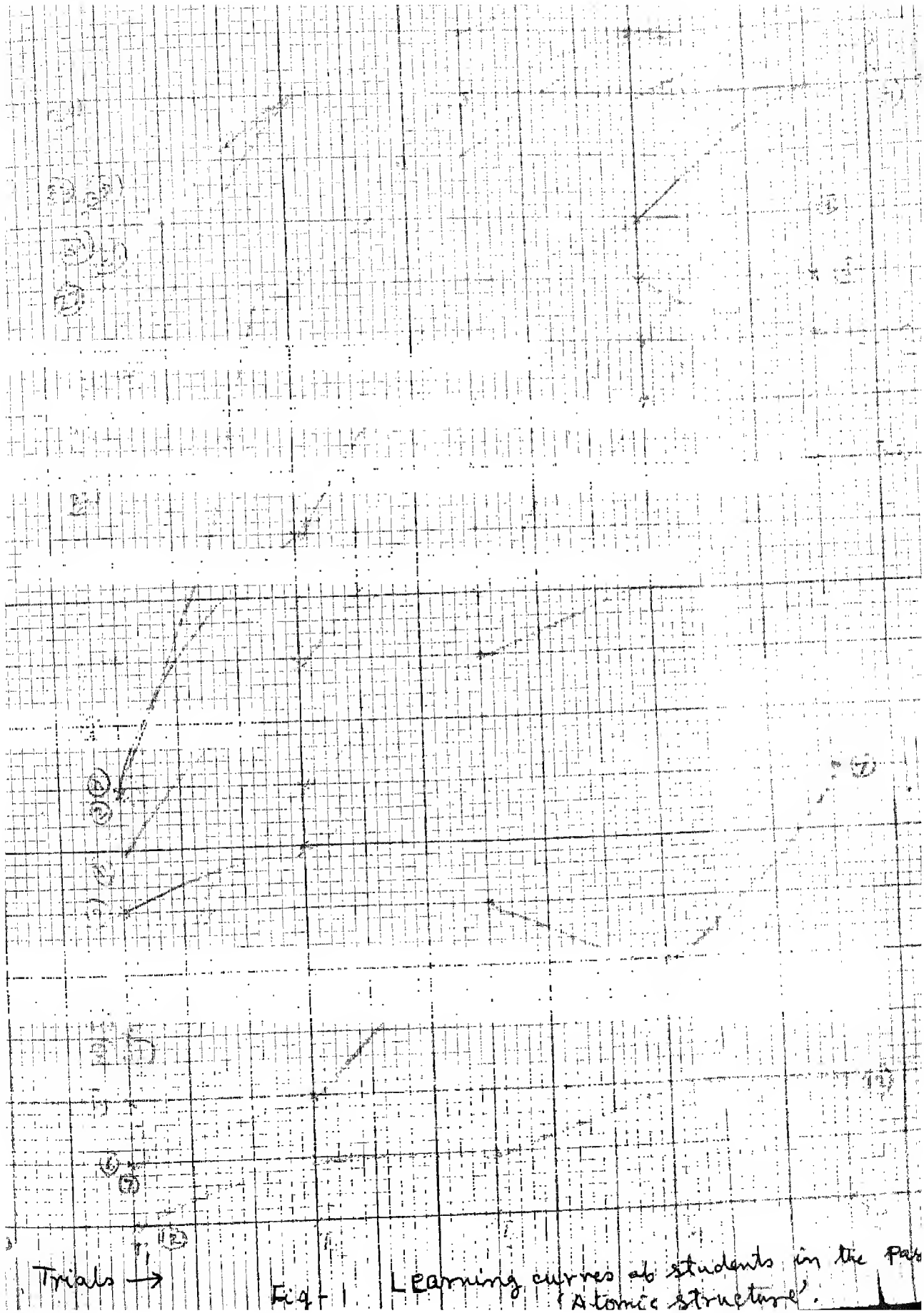

Fig 1 Learning curves of students in the Pa
'Atomic Structure'.

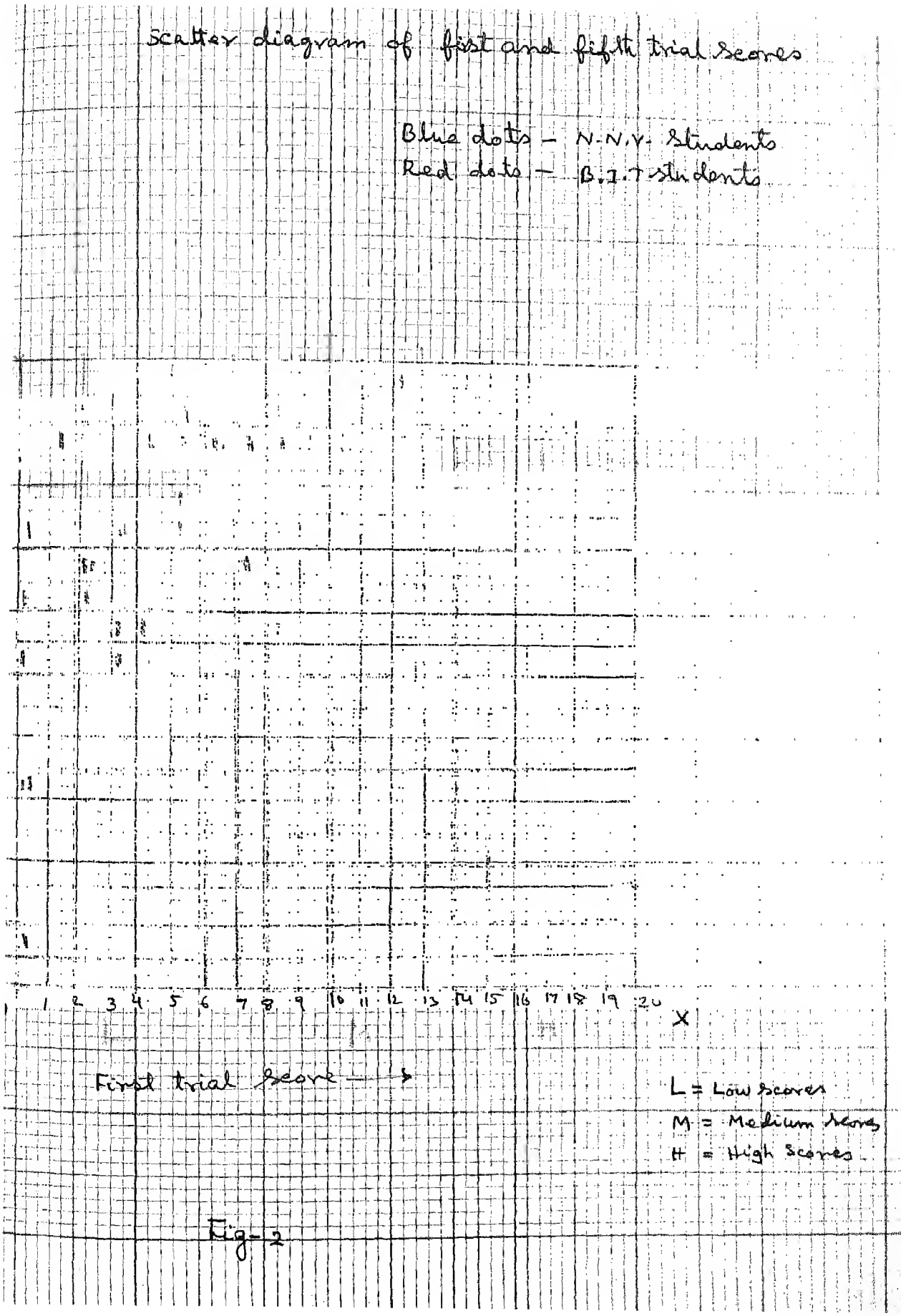
Scatter diagram of first and fifth trial scores
Blue dots – N.N.Y. Students
Red dots – B.I.T. students
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
X
First trial score →
L = Low scores
M = Medium scores
H = High scores

Fig-2

classification of learning curves

X-axis → Trials
Y-axis → Scores

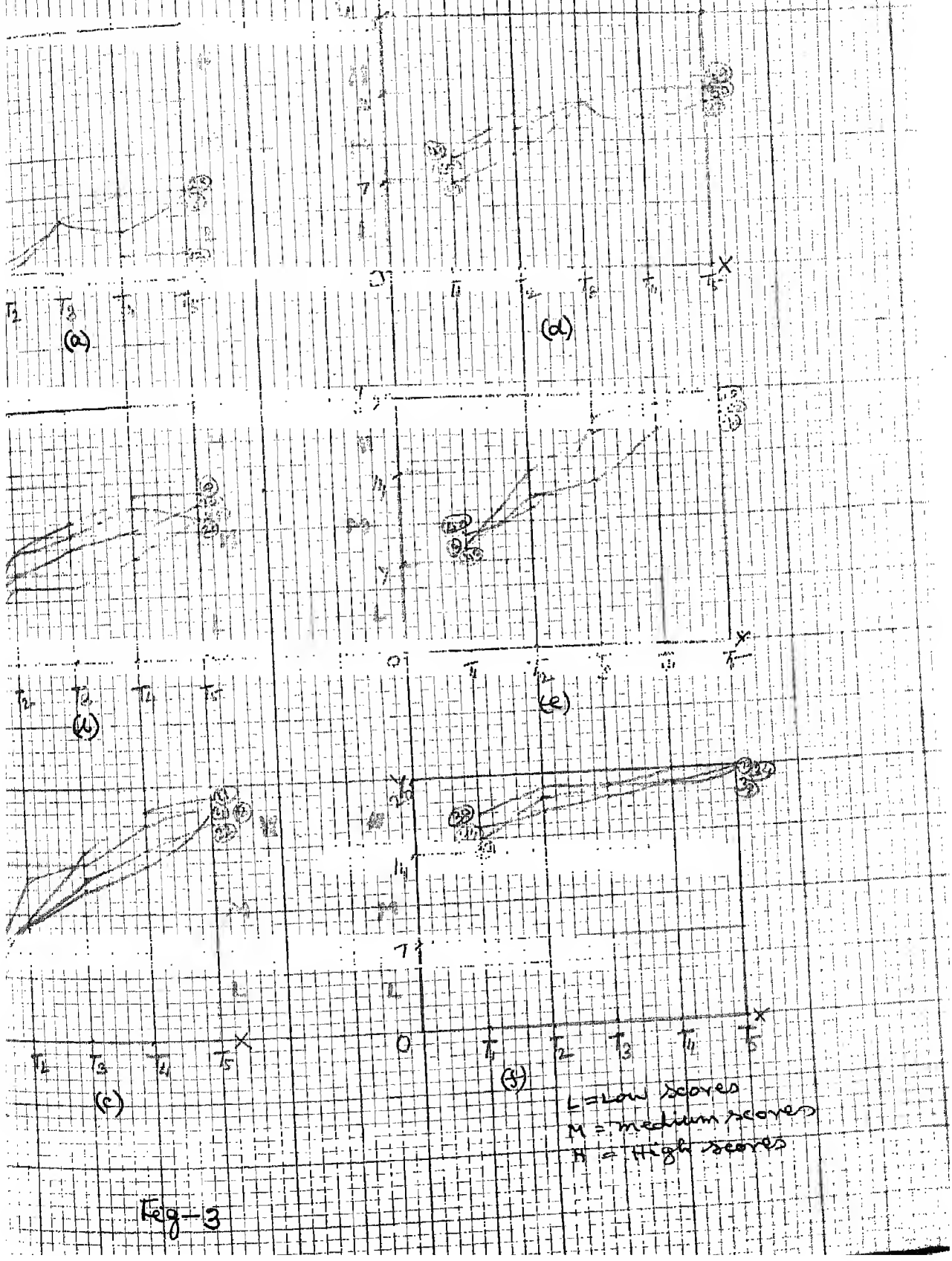

Fig-3

Chart of scores of the students in different trials

Name of the Institution	Name of the Passage	Code No. of Students	Scores in different trials				
			T_1	T_2	T_3	T_4	T_5
NARENDRANATH VIDYAMONDIR	ATOMIC STRUCTURE	1	1	4	15	13	13
		2	7	11	14	16	18
		3	8	14	17	19	18
		4	2	9	12	14	18
		5	13	18	19	20	20
		6	1	6	9	13	15
		7	1	2	5	4	7
		8	3	9	11	13	13
		9	7	11	15	16	16
		10	5	6	9	10	12
		11	6	9	11	18	19
		12	0	1	1	2	2
		13	3	7	10	15	14
	RADAR	14	4	10	14	14	15
		15	6	14	17	18	18
		16	9	14	17	18	18
		17	4	9	11	11	15
		18	5	13	14	17	18
		19	3	7	10	15	14
		20	1	6	6	9	11
		21	4	7	8	13	12
		22	1	9	13	15	17
		23	0	1	5	7	7
		24	6	13	13	16	16
		25	4	9	10	12	11
		26	5	10	13	15	15

TABLE 1 (Contd)

Chart of scores of the students in different trials (contd.)

ame of the nstitution	Name of the Passage	Code No. of Students	Scores in different trials				
			T_1	T_2	T_3	T_4	T_5
IRLA NSTITUTE F TECHNOLOGY SCIENCE	ATOMIC STRUCTURE	27	15	18	19	20	20
		28	14	17	19	20	20
		29	18	18	19	19	19
		30	7	16	18	18	18
		31	14	18	19	19	19
		32	17	19	20	20	20
		33	13	15	18	19	19
		34	16	17	18	19	20
		35	16	17	17	19	19
		36	3	10	13	13	14
		37	9	11	13	12	13
		38	17	19	19	19	20
	RADAR	39	11	17	17	18	18
		40	9	11	18	19	19
		41	10	11	16	17	18
		42	6	11	11	14	15
		43	8	12	13	17	18
		44	9	11	14	18	18
		45	8	9	12	14	15
		46	17	18	18	18	19
		47	11	13	18	18	18
		48	6	11	14	14	15
		49	9	12	13	12	14
		50	8	9	13	14	14

TABLE 2

Values of average rate of learning (e_1) of the students

Code No. of Students	Average rate of learning (e_1)	Code No. of Students	Average rate of learning (e_1)
1	2.913	26	3.042
2	3.504	27	3.303
3	3.606	28	3.738
4	3.574	29	3.362
5	3.739	30	3.507
6	3.127	31	3.481
7	1.330	32	2.806
8	2.666	33	3.448
9	3.820	34	3.609
10	2.322	35	3.444
11	3.896	36	2.800
12	0.432	37	2.530
13	3.594	38	3.530
14	3.002	39	3.364
15	3.599	40	3.827
16	3.509	41	3.493
17	2.502	42	2.910
18	3.579	43	3.514
19	2.975	44	3.583
20	2.201	45	2.910
21	2.521	46	3.352
22	3.513	47	3.502
23	1.351	48	2.921
24	3.155	49	2.502
25	2.241	50	2.752

Acceleration of learning (o_2) of the students

Code No. of Students	Acceleration of learning (o_2)
1	- .246
2	- .638
3	- 1.093
4	- .106
5	- 1.605
6	+ .103
7	+ .096
8	- .485
9	- .849
10	- .326
11	- .432
12	+ .017
13	- .224
14	- .629
15	- .980
16	- 1.139
17	- .311
18	- .682
19	- .224
20	- .016
21	+ .096
22	- .271
23	- .121
24	- .825
25	- .633

Code No. of Students	Acceleration of learning (o_2)
26	- .447
27	- 1.704
28	- 1.587
29	- 1.939
30	- 1.397
31	- 1.728
32	- 1.555
33	- 1.510
34	- 1.629
35	- 1.65
36	- .592
37	- 1.051
38	- 1.881
39	- 1.458
40	- .708
41	- .915
42	- .637
43	- .713
44	- .762
45	- .656
46	- 1.824
47	- 1.228
48	- .805
49	- 1.046
50	- .790

Appendix

Calculation of c_1 and c_2

Let $c = (c_0, c_1, c_2)$, $x = \begin{matrix} 1 & 1 & \dots & \dots & 1 & 1 \\ 1 & 2 & \dots & \dots & t & k \\ 1-k & 4-2k & & & t^2-tk & 0 \end{matrix}$

$t = 1, 2, \dots\dots k$

$\hat{p} = (\hat{p}_1, \hat{p}_2, \dots\dots \hat{p}_t, \dots\dots \hat{p}_k)$

Then $p = cx$ which is equation (3)

If p is replaced by $\hat{p}$ which is a row vector of observed performance scores, then the inverse of x will have the desired property of minimizing $p - \hat{p}$. Because x is not a square matrix, it has no inverse, however the quasi-inverse matrix $x^1 (xx^1)^{-1}$ does exist and has least square properties. Thus $c = px (xx^1)^{-1}$. Let $w = x (xx^1)^{-1}$,

Then $c = pw$ .... (6)

The learning parameters were obtained from equation (6) by performing the appropriate matrix multiplication between the row vector of performance scores and the weight vectors associated with a given parameter. In as much as most of the learning tasks reported in this study were novel to the subjects, their co-parameter were set at zero, or at a chance level. The weight vectors used to compute learning parameters for five trials appear in the next the next page.

Weights for computing learning parameter :

$\sigma_o = 0$, no. of trials = 5

Trial no.	Trial weights σ_1	Trial weights σ_2
1	- .2981	- .5280
2	- .02857	- .07143
3	.00373	- .0559
4	.06708	- .00621
5	.17149	.07764

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ATOMIC STRUCTURE, NUCLEUR FISSION AND ATOMBOMB

Atoms consist of mainly three kinds of particles namely electron, proton and neutron. Electron is negelively charged and has almost no mass. Proton has a positive charge whose mass is equal to that of a hydrogen atom. Neutron has no charge, but mass equal to that of proton. The central part of atom is known as neucleus which consists of protons and neutrons. Electrons move round the nucleus like the planets of the solar system. Some atoms are chemically identical and have different masses. They are known as isotopes. The number of protons in an atom is equal to the number of electrons in it. This number is known as atomic number. The nucleus of hydrogen consists of one proton only. Nucleus of heavy hydrogen or deuterium contains one proton and one neutron. Hydrogen, deuterium and helium can be sybolically written as ${}_1H^1$, ${}_1H^2$ and ${}_2He^4$. Index indicates the atomic mass and the subscript the atomic number.

When slow neutrons are bombarded to uranium atoms, they are split into two nearly equal parts and a tremendous amount of energy comes out. This is known as 'fission'. In this process one or more slow neutrons are liberated. They fall on the uranium atoms causing fission again. The subsequent fission sets free several slow neutrons which again starts reaction producing enorm energy and liberating more neutrons. This continuous process is known as chain reaction.

All atoms of uranium do not split into two parts. The nucleus of ${}_{92}U^{235}$ may be disintegrated to producing enormous energy. Plutonium of atomic weight 239 also splits into two nearly equal parts and produces energy of fission. The energy of fission caused by the chain reaction is the reason for causing disastor

ANSWERSHEET TO PASSAGE ON ATOMIC STRUCTURE, NUCLEAR FISSION & ATOM-BOMB.

On the basis of the passage you have read, fill up the following nks with appropriate word or pharase which will make a complete entific sense:

The particle which moves round the central part of an atom is known as _____.

The mass of a neutron is the same as that of a _____atom.

Protons and neutrons are contained in the _____of the atom.

Atoms having different atomic masses and similar chemical properties are called_____.

The atomic number of heavy hy-drogen is _____.

The atomic mass of heavy hydrogen is _____.

The atomic number of helium is _____.

The number of proton/protons in helium is _____.

The atomic number of uranium is _____.

Uranium atoms are split into two parts when _____are bombarded to them.

In atom bomb the velocity of reutron is diminished by using____

The atomic mass of helium is _____.

The number of meutrons in helium is _____.

During separation of uranium atoms a tremendous energy is produced and some _____ come out.

The process of splitting of atoms and energy formation is known as _____.

The continuous process of separation of atoms and energy formation is due to formation of _____ in each separation.

The process of successive splitting up of atoms is known as _____.

Energy of fission = _____X square of velocity of light.

Atombomb consists of a mixture of uranium, ___ graphite, and _____.

The atomic weight of uranium used in preparing atombomb is _____.

RADAR

Radar is a scientific wonder. The name radar is a short from of the phrase Radio Detection and Ranging. It discovers and determines the position of objects by means of radio waves.

In a radar system, short pulses of high frequency radio waves are sent through space at the rate of a few thousand a second. Each pulse is about a millionth of a second long. If the radio waves strike an object, some of them return to the place from which they were sent. During the pause between the pulses, the radar receiver detects the waves as they return from the object. The time required for the pulse to travel to the object and to return can be measured.

Radio control, a special type of radar, is usually used in the time of war. In radio control there are two radars: one for tracking the tarhet, the other the missile. Missiles are instruments which can follow targets continuously moving.

The target tracking radar and the missile are connected to a computer. The path of the target and the path through which the missile should follow to hit the target are computed in the computer. This information is passed to the missile through a radio channel and it changes its course accordingly.

The guidance system of a missile has devices which measure the deviations from the desired course. These deviations produce mechanical forces in the control system of the missile. Then the missile goes in the right direction to hit the target properly.

In present day war radar is unavoidable. It is an important weapon for crushing the enemy planes in the present Indo-Pak war. Again, if a seaman becomes seriously ill, he can be hospitalised by a coast guard who can locate the ship by radar. Air planes

Answer sheet to passage on RADAR

On the basis of the passage you have read, complete the lowing blanks with appropriate word or phrase which will make omplete scientific sense:-

Radio Detection and Ranging is done by the scientific instruement known as _____.

The medium of sending short pulses is _____.

The short pulses have frequency _____persecond.

Each pulse is about a _____of a second long.

The radio waves from radar strike _____ and return to the place from which they were sent.

The radio wave are detected by _____when they return from the object.

Objects are located by the _____required for the pulse to go to the object and to return back.

Radar used in war is known as _____.

The first radar of radio control locates the _____.

The second radar of radio control is known as _____.

A computer is connected with _____of radio control.

The path of the target is traced on the _____.

The instrument which moves continuously to hit the target is known as _____.

The information of path to be followed by missile is communicated there through_____.

The deviations from the desired course are measured and they produce_____in the control system of the missile.

Frequency of a sound wave is the number of _____persecond.

Radar is an important weapon for crushing enemy_____.

If a ship is drowned in the sea, its position can be located by _____.

By radar, astromomer can study _____.

Air planes can land safely by the help of radar in _____ weather.